Large Eddy Simulations of a Fully Integrated Aircraft Engine Combustor and High Pressure Vane

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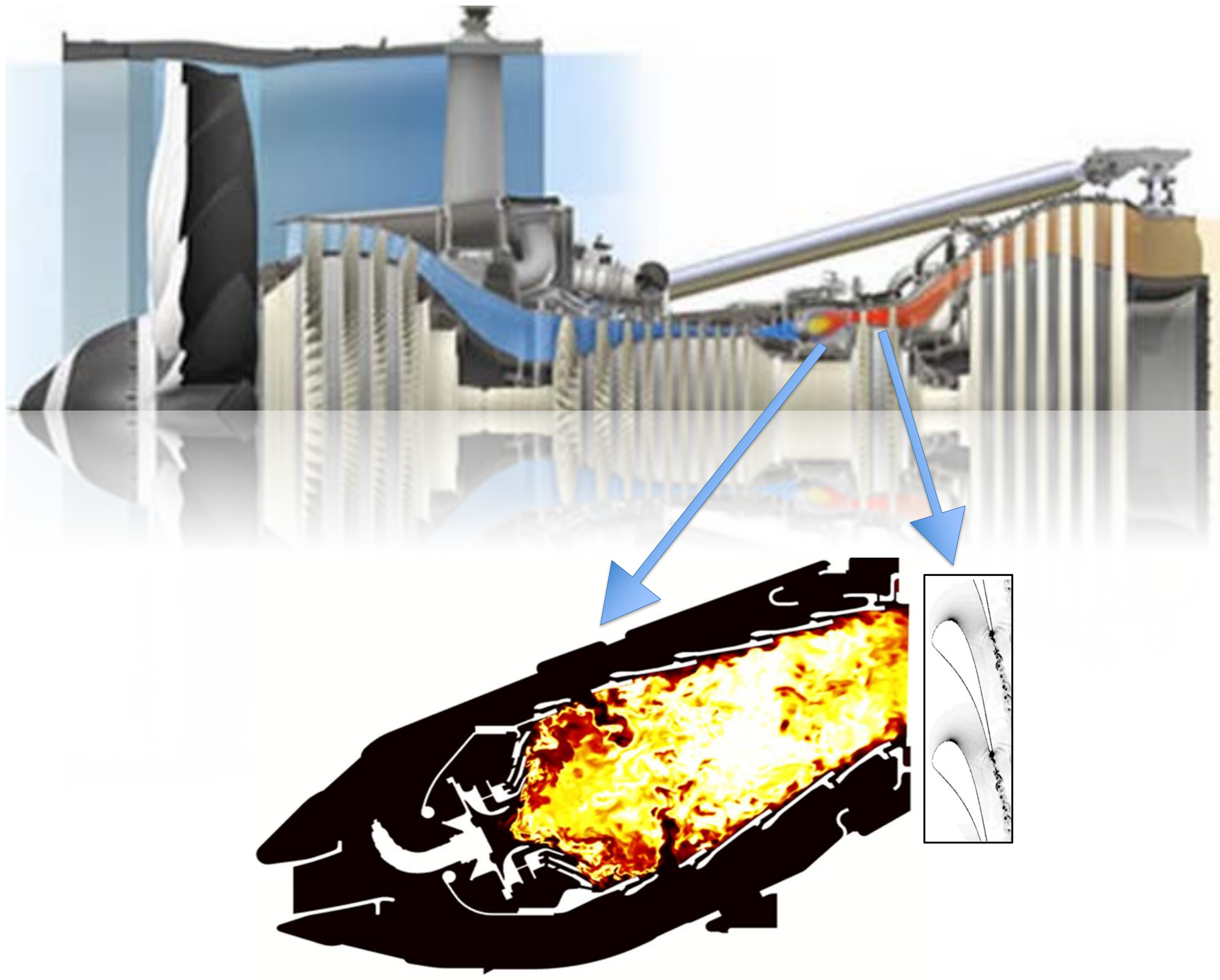
HPC4 MANUFACTURING

Challenge

Combustor and high pressure turbine (HPT) integration is a complex multi-scale and multi-physics problem. Experiments and test facilities are very expensive. HPC simulations will help understand the complex physics of interaction between combustor and HPT. The insight gained from the simulations will be leveraged for improved aerodynamic performance and increased turbine durability.

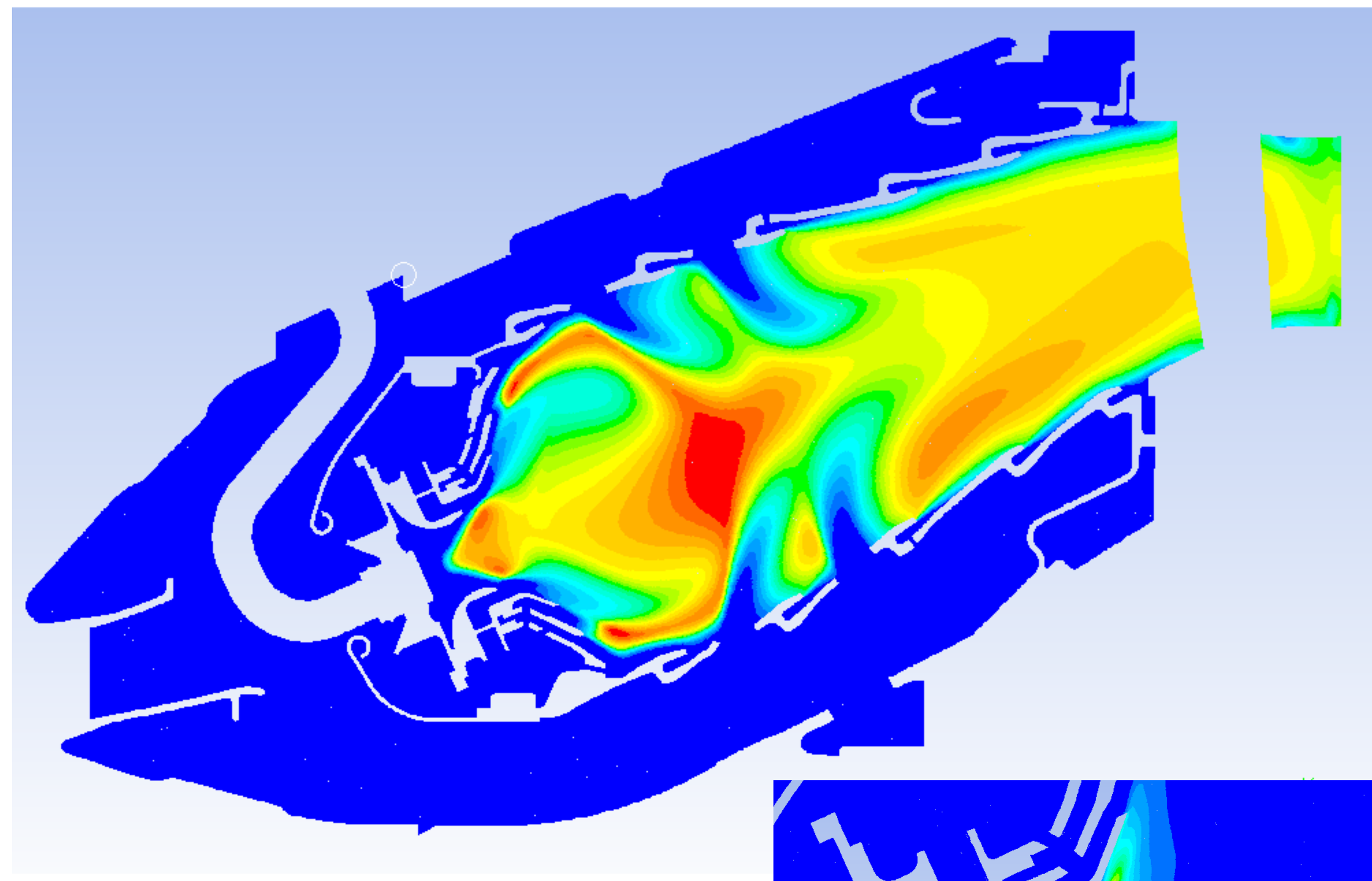


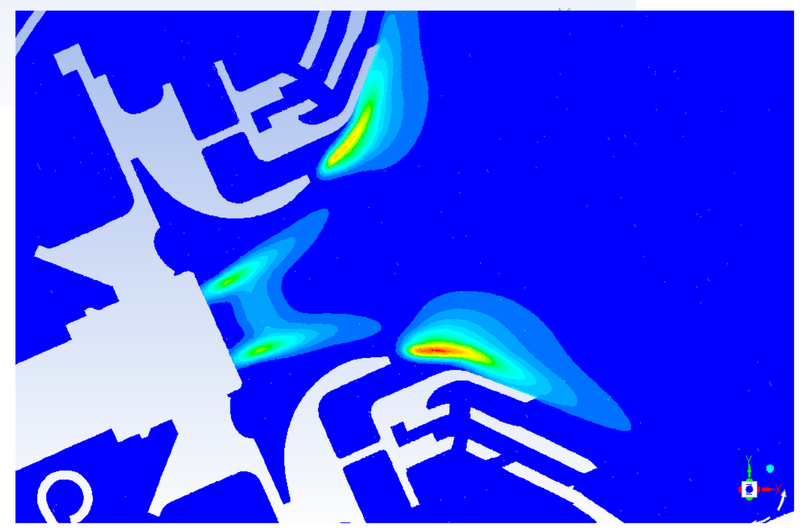
Turbulence intensity exiting combustor can exceed 30%. Scale resolved and coupled models of the combined combustor-HPT domain are needed to capture the physics of turbulence. The computationally intensive nature of these simulations requires DOE's facilities and expertise in HPC and Computational Fluid Dynamics (CFD).

Approach

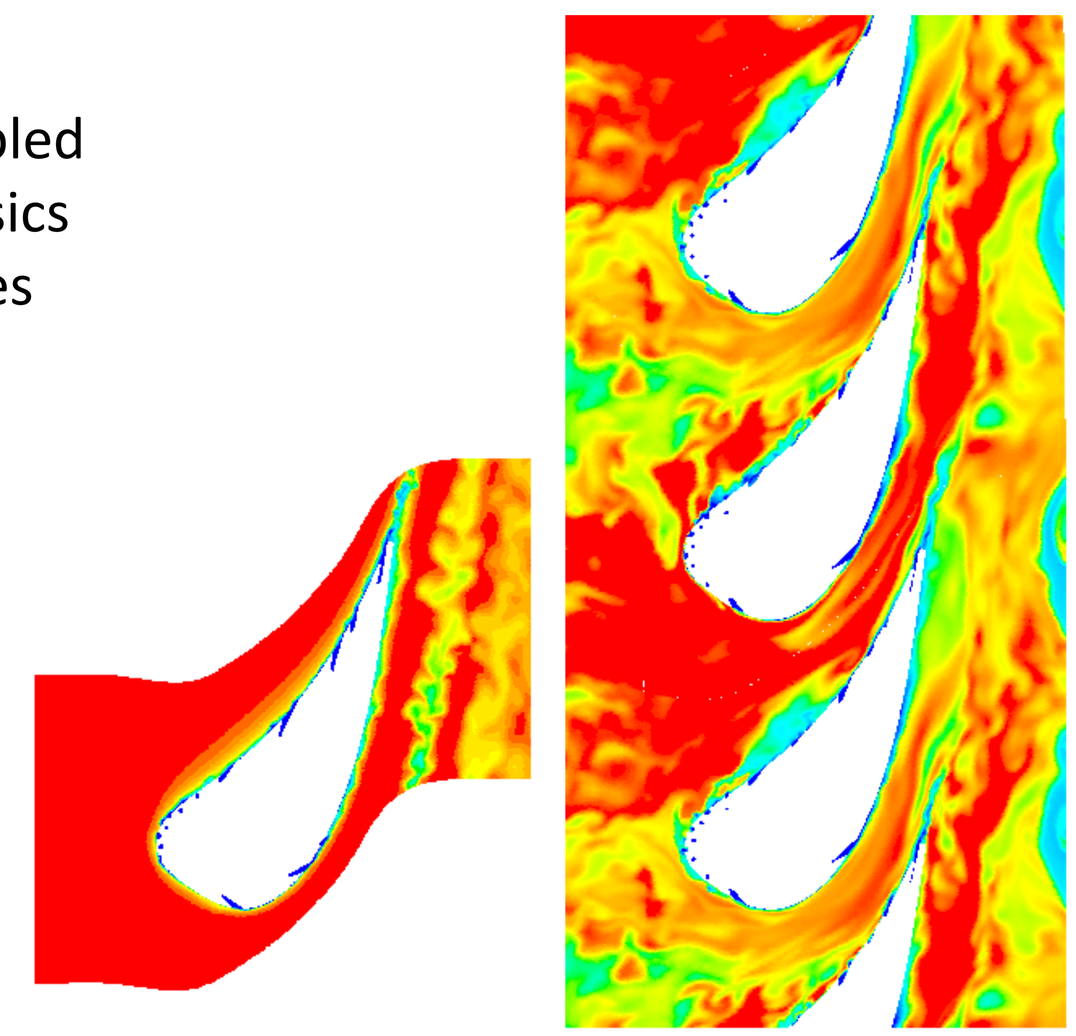
A fully coupled Large Eddy Simulation (LES) of combustor and Stage-1 nozzle (S1N) is being performed. Two clocking positions are being simulated. Reynolds Averaged Navier-Stokes (RANS) simulations are used as baseline and to supply boundary conditions. Simulations performed using:

- **Ansys/Fluent** – a commercial code currently in use at GE with impact on the design process
- **CharlesX** – a scalable LES code developed by Stanford and DOE under the PSAAP program and holds the promise of achieving future goals of fully integrated gas turbine HPC simulations.





Results from baseline RANS simulation performed using Fluent. (Top) Temperature isocontours in the combustor and nozzle exit. (Right) Scalar dissipation rate isocontours near the injector. The rainbow color scale varies from red (high) to blue (low).

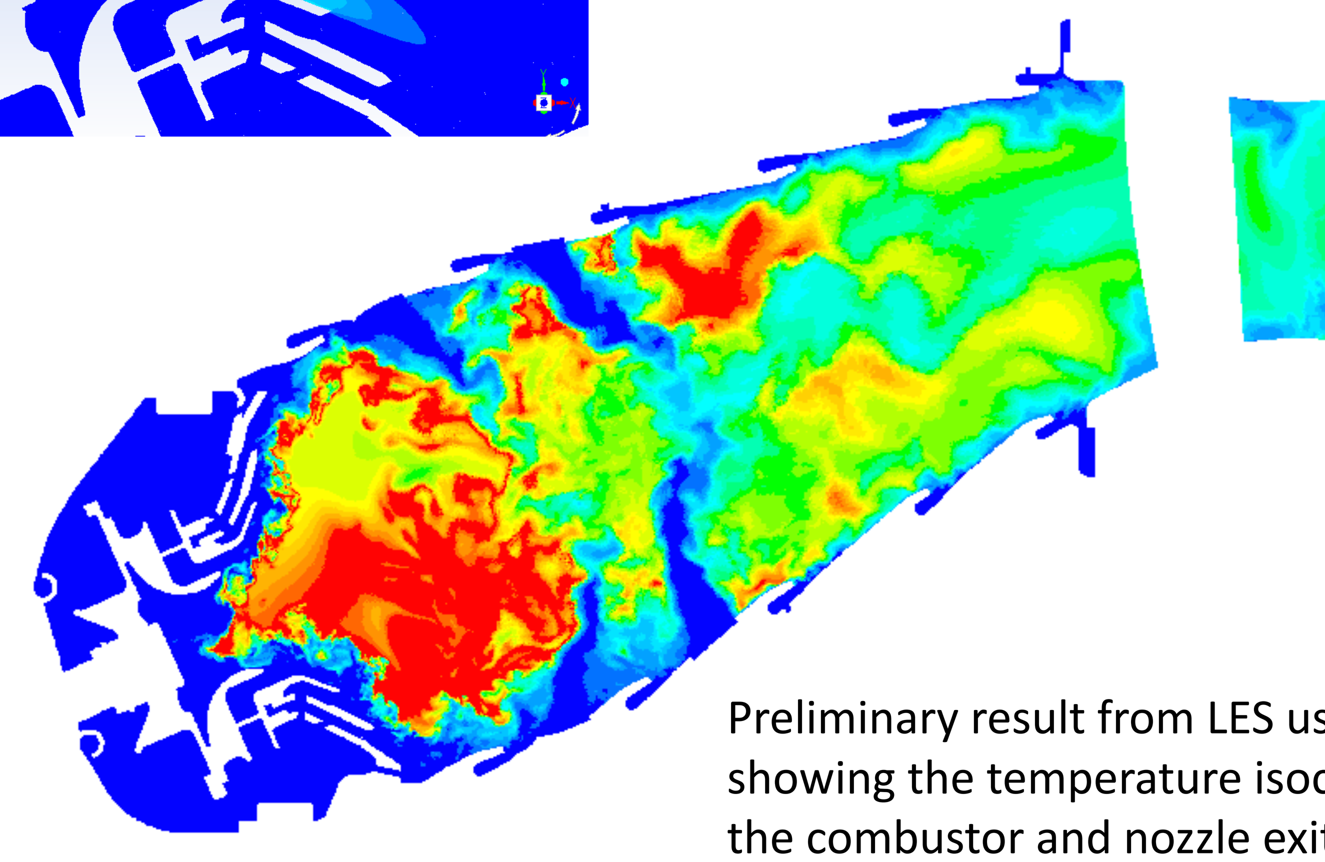


Instantaneous hybrid LES simulation of high pressure turbine stage 1 nozzle. (Left) Vane alone analysis. (Right) Coupled combustor vane analysis. (Kopriva and Laskowski, 2015).

Results

Baseline RANS simulations have been conducted using Fluent. The RANS solution was analyzed to determine the length scales and the requirements for mesh refining for the LES. The RANS solution also provides the boundary flow profiles for the LES.

LES setup and execution are in progress. LES will be conducted simultaneously using Fluent and CharlesX. Preliminary results confirm that the LES captures the unsteadiness and flow physics associated with the hot streaks.



Preliminary result from LES using Fluent showing the temperature isocontours in the combustor and nozzle exit.

Benefits

Design optimization of gas turbine components can be worth up to 2% specific fuel consumption, 1.5% reduction in weight, 3% reduction in cost and 20% improved component life.

According to the FAA, the US consumed approximately 35.6 billion gallons of aviation fuel in 2012. Jet A fuel is currently approximately $1.5/gallon. Therefore, technologies that can enable even a 0.1% Specific Fuel Consumption (SFC) savings can have a multi-billion dollar impact on the US economy while reducing carbon based emissions.

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